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Substitute Specification

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Refrigeration installation and method for operating a refrigeration installation

BACKGROUND

(1) FIELD OF THE INVENTION

[0001] The invention relates to a refrigeration installation having at least one refrigeration consumer, which includes at least one evaporator, having at least one feed line and at least one discharge line, via which the refrigerant or refrigerant mixture is fed to the refrigeration consumer(s) and discharged from the refrigeration consumer(s), respectively, the evaporator(s) being assigned expansion members.

[0002] Furthermore, according to a first alternative, the invention relates to a method for operating a refrigeration installation in which the refrigeration compressor(s) is/are assigned modified expansion valves and modified linear compressors.

[0003] According to a second alternative, the invention relates to a method for operating a refrigeration installation, in which the conventional expansion valve(s) and the conventional compressor(s) of the refrigeration consumer(s) is/are assigned bypass lines.

[0004] In the text which follows, the term "modified expansion valves" is to be understood as meaning all

expansion valves which, in addition to the primary function of "expansion of a liquid", have the secondary function of "realization of a fluid connection". The term "modified compressor" in the text which follows encompasses all compressors which, in addition to the primary function of "compression of a gas", also allow the secondary function of "realization of a fluid connection".

[0005] The terms "conventional expansion valves" and "conventional compressors" in the text which follows are to be understood as meaning all known designs of expansion valves and compressors which do not have the above-mentioned secondary function.

[0006] Refrigeration installations of the generic type are used for example in supermarkets or hypermarkets, where they generally supply a multiplicity of refrigeration consumers, such as cold stores, refrigerator cabinets and/or freezer cabinets. For this purpose, a one-component or multicomponent refrigerant or refrigerant mixture circulates inside them. A refrigeration installation of this type - as is known from DE-C 39 28 430 - has a liquefier, in which the pressurized refrigerant (mixture) is condensed by indirect heat exchange, preferably against outside air.

[0007] The liquid refrigerant (mixture) from the liquefier is fed to a collection vessel that is optionally to be provided. Within a refrigeration installation, there must always be enough refrigerant to ensure that the evaporators

of all the refrigeration consumers can be filled even during the maximum demand for refrigeration. However, since when the demand for refrigeration is lower some evaporators are only partially filled or are even completely empty, the excess refrigerant (mixture), during these times, has to be collected in the collection vessel provided for this purpose.

[0008] The refrigerant (mixture) is fed from the collection vessel to the refrigeration consumers via at least one liquid line. An expansion device, preferably an expansion valve, in which the refrigerant (mixture) flowing into the refrigeration consumer or the evaporator(s) of the refrigeration consumer is expanded, is connected upstream of each refrigeration consumer. The refrigerant (mixture) which has been expanded in this way is evaporated in the evaporators of the refrigerant consumers and thereby cools the corresponding refrigeration cabinets or cold stores.

[0009] The evaporated refrigerant (mixture) is then fed via a suction line to a compressor unit. These compressor units may be of single-stage or multistage design. The individual compressor stages generally have a plurality of compressors connected in parallel, which compress the refrigerant (mixture) and pass it back, via a riser, to the liquefier which has already been mentioned. Whereas the compressor unit is normally positioned, for example, in a machine room arranged in the basement of a supermarket, the liquefier is located on the roof of the supermarket.

[0010] The compressors used are generally oil-lubricated reciprocating piston compressors which are driven in rotation. One drawback in this case is that corresponding measures have to be taken to allow the oil released from the reciprocating piston compressor to be separated from the refrigerant (mixture). Furthermore, it is generally necessary to ensure that the oil which has been separated off is fed back to the reciprocating piston compressor(s). To enable the oil to be separated off, the mixture of refrigerant and oil first of all has to be passed to specific points within the cycle, and consequently minimum velocities have to be reached in rising suction and pressure lines, since the oil would not otherwise be entrained. These minimum velocities mean small pipe diameters, resulting in additional, undesired pressure losses and therefore energy losses. To avoid these pressure and energy losses in risers, it is necessary to split lines, but this in turn results in increased installation outlay. Therefore, process aspects are undesirably closely linked to economic aspects.

[0011] As an alternative to the procedure described above, the system of a cold vapor refrigeration installation, in which a distinction is drawn between subcritical (with reliquefaction) and supercritical (with gas recooling) operation, so that a "gas cooler" is used instead of the "liquefier" component, it is also possible for a gaseous

refrigerant (mixture) to circulate in a refrigeration installation, which under the given boundary conditions (pressure, temperature, etc.) is not in liquid form at any time. This is then what is known as cold gas refrigeration installation, also referred to as a Joule, Stirling or Gifford-McMahon installation.

[0012] The text which follows will simply use the term "liquefier". If the process in question is a cold vapor compression process in the two-phase range, it is actually a liquefier that is used. In the case of a supercritical procedure or gas processes, the term "liquefier" in turn stands for a gas cooler. It is essential for heat to be dissipated from the cycle process. The liquefaction can take place in an air-cooled apparatus, in an intermediate-pressure separator or alternatively by means of a further assembly connected in a cascade. A cascade connection is present whenever there is a further refrigeration machine which is operated at a higher temperature level and which alone dissipates the heat of liquefaction to the environment. The refrigeration set is in this case dependent on this refrigeration machine and in turn transfers its heat of liquefaction thereto. By way of example, it is possible for a standard cooling set to be connected upstream of a freezing set, in which case the two cooling sets may have different refrigerants or refrigerant mixtures.

[0013] If what are known as normal cooling points and what

are known as freezing points are present inside a hypermarket or supermarket, these are generally supplied by means of separate refrigerant cycles; this therefore means that there are at least two refrigeration installations as described in DE-C 39 28 430.

[0014] The refrigeration installation or the evaporators arranged in the refrigeration consumers have to be defrosted at regular intervals, since frosting or icing of the evaporators leads to a reduction in the efficiency of the evaporators. One defrosting option is electrical defrosting, in which the evaporators are defrosted by means of electrical heaters arranged in and/or on them. However, this procedure leads to an undesirable increase in the consumption of electrical energy.

[0015] What is known as compressed gas defrosting is a recommended alternative to the electrical defrosting described above. In this case, compressed-gas lines are laid between the gas space of the collection vessel connected downstream of the liquefier and each evaporator or evaporator module, and refrigerant, which is preferably at a temperature of between 35 and 45°C, is fed from the collection vessel to the evaporators or evaporator modules via these compressed-gas lines. However, the installation outlay for this compressed-gas defrosting is relatively high, since either a separate compressed-gas line has to be provided for each evaporator or each evaporator module or, as is customary in

the two-wire system, switching valves and a second set comprising the same refrigerant (mixture) are required. Furthermore, there is the possibility of defrosting by means of circulated air at temperatures above approx. 2°C.

SUMMARY OF THE INVENTION

[0016] It is an object of the present invention to provide a refrigeration installation of the generic type which in terms of investment and operating costs and also reliability has advantages over the refrigeration installations of the prior art.

[0017] To achieve this object, the invention proposes a refrigeration installation which is distinguished by the fact that

[0018] - the expansion members are designed as modified expansion valves and/or as modified linear expansion machines or are assigned bypass lines, and

[0019] - each refrigeration consumer is assigned a modified linear compressor or a conventional compressor, which includes a bypass line,

[0020] - the modified expansion valve(s) and/or the modified linear expansion machine(s) and/or the modified linear compressor(s) having a working position which allows flow to pass through without a significant pressure drop.

[0021] Most linear compressors operate as oil-free cryogenic

Stirling coolers at extremely low temperatures and extremely low powers, i.e. in cold-vapor compression. In cold-vapor compression, linear compressors have only been implemented for a few years and have hitherto not been deployed extensively. In the cooling sector, the applicant is only aware of one application, namely the use of a linear compressor in a domestic refrigerator. A drawback of linear compressors is that their production costs have hitherto been well above those of reciprocating-piston compressors driven in rotation, but of a similar order of magnitude to inverter compressors. Only in the 1960s were efforts made to exploit the advantages of linear compressors. The principle of friction-free mounting of the piston only dates from this time. Even so, it was only in the 1990s that improvements were made to the operational reliability, by virtue of reliable electronic reciprocating controllers. In this case, it was or is necessary in particular to ensure that for example fluctuating pressures do not lead either to the piston striking the cylinder head or to premature termination of the reciprocating operation at the top dead center, associated with an excessive damage volume and volumetric or energy drawbacks of re-expansion.

[0022] Linear compressors have the advantage of allowing continuously variable power control, which is realized by reciprocating control. Furthermore, they can be operated without oil. Furthermore, the condensate which is inevitably

formed during defrosting operation does not cause any damage to them. Furthermore, they are superior in energy terms to oil-lubricating reciprocating piston compressors which are driven in rotation.

[0023] Although they are operated without oil, the oil-lubricated compressors which are driven in rotation are superior in energy terms. This results on the one hand from the efficient linear motor and on the other hand from the elimination of the mechanical losses, of which about 80% occur at the driving mechanism and about 20% at the piston. The piston of a linear compressor is mounted without contact and can be guided by what are known as flexible bearings, which allow axial mobility combined with radial rigidity. This ultimately means a spring combination of uncoiling and coiling springs which impart a rotary movement to the piston about its longitudinal axis in addition to its periodic translatory movement.

[0024] Since they do not have any sliding-contact bearings, linear compressors can be operated without oil. This absence of oil gives rise to numerous advantages. In the case of compressed-gas defrosting with condensation, the bearings, which have hitherto been relatively vulnerable, can no longer be damaged by liquid refrigerant (mixture). The formation of acid which is known when using lubricating oils and can lead to burn-out of the winding of built-in motors, has hitherto been more or less effectively avoided by the use of

refrigerant dryers. These molecular sieve dryers can now be dispensed with unless the water content is so high that there is a risk precipitation of ice during the expansion. Irrespective of this, it is recommended that dirt filters be provided immediately upstream of the expansion valves or machines.

[0025] Linear compressors also have the advantage of not being damaged by the pumping of liquid, unlike other designs of compressor. The pumping of liquid is of relevance in particular after the end of a defrosting process, since at this time under certain circumstances condensate may still be present in the defrosted evaporators, and this condensate is sucked in by the compressor when it starts to operate again. However, it should expediently be ensured that liquid is pumped carefully. This means beginning with small reciprocating strokes, in order to limit the maximum power of the compressor during the conveying of liquid and to protect the working valves and reciprocating movement dampers. A design solution in which a disk valve as pressure valve replaces the cylinder head has also already been proposed; this leads to very high operational reliability.

[0026] Unlike the known refrigeration installations from the prior art, it is now possible to implement circuits in which the feed and discharge lines assigned to the refrigeration compressor(s) contain the liquid that is to be injected as well as the compressed gas of the compressor(s). Therefore,

on the one hand there is no need for a central suction line, and on the other hand the compressors are no longer spatially separate from the consumer(s), but rather are located in the immediate vicinity of the refrigeration consumer(s).

[0027] The compressor sets which it has hitherto been necessary to provide in refrigeration installations can now be dispensed with, since each consumer is assigned at least one dedicated compressor. Therefore, each consumer can be controlled individually and, moreover, continuously by means of its own compressor. Unlike in the known procedures or refrigeration installations, this individual control can now take place irrespective of the temperature level in the return line, since the return or discharge line now no longer represents the suction line, the pressure of which is dependent on the evaporation temperature, which predetermines the temperature of the refrigeration consumers, but rather represents the pressure line.

[0028] If this is not impossible on account of other boundary conditions, it is possible, for example, for freezer cabinets to be temporarily used and operated as standard refrigerator cabinets and/or display shelves for fresh meat and at times for dairy products. In the simplest case, this changeover is effected by adjusting a temperature selection button on the refrigeration cabinet in question. Furthermore, a pressure line has a smaller diameter compared to the corresponding suction line and moreover does not require any

insulation.

[0029] As has already been mentioned in the introduction, the invention also relates to two alternative methods for operating a refrigeration installation of the generic type in order to realize a compressed-gas defrosting method.

[0030] In this context, the first alternative of the method according to the invention for operating a refrigeration installation is distinguished by the fact that during the defrosting phase of the refrigeration consumer or at least one of the refrigeration consumers, the modified expansion valve(s) and the modified linear compressor(s) of the refrigeration consumer(s) which is/are to be defrosted is/are moved into the working position in which through-flow without a significant pressure drop is possible.

[0031] The second alternative of the method according to the invention for operating a refrigeration installation is characterized in that during the defrosting phase of the refrigeration consumer or at least one of the refrigeration consumers, the associated bypass lines are opened and the associated conventional expansion valve(s) and the associated conventional compressor(s) are taken out of operation.

[0032] The refrigeration installation according to the invention, the methods according to the invention for operating a refrigeration installation and further configurations of the refrigeration installation according to

the invention and of the methods according to the invention will be explained in more detail on the basis of the exemplary embodiments illustrated in figures 1, 2 and 3.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] FIG. 1 shows a refrigeration installation;

[0034] FIG. 2 shows an alternative embodiment of a refrigeration installation; and

[0035] FIG 3 shows another embodiment of a refrigeration installation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0036] Figure 1 shows a refrigeration installation according to the invention, which is used to supply three refrigeration consumers V', V'' and V'''. Of course, there may be any desired number of refrigeration consumers. The refrigerant or refrigerant mixture - referred to below simply as "refrigerant" - is fed to the above-mentioned refrigeration consumers via a (central) feed line 1 and lines 1', 1'' and 1''' which branch off from this feed line 1.

[0037] According to the invention, either a modified expansion valve a, b or c is connected upstream of the

evaporator of each refrigeration consumer V', V'' and V''' or - as illustrated in figure 2 - the upstream conventional expansion valve a' has a bypass line 4, represented by dashed lines. Figure 2 shows, on the basis of the refrigeration consumer V', by way of example, an alternative configuration of the refrigeration installation according to the invention to the embodiment illustrated in figure 1. As an alternative to the modified expansion valves a, b and c illustrated in figure 1, it is also possible to use modified linear expansion machines.

[0038] After expansion has taken place in the valves a, b and c or a' described above, the expanded refrigerant is fed via the lines 2', 2'' and 2''' to the evaporators of the refrigeration consumers V', V'' and V''', in which it is evaporated.

[0039] The evaporated refrigerant is then fed back to the (central) return line 3 via the return lines 3', 3'' and 3''' by means of the modified linear compressors x, y and z. Instead of the modified linear compressors x, y and z illustrated in figure 1, it is also possible to provide a conventional compressor x' which has a bypass line 5, illustrated by dashed lines; this embodiment of the refrigeration installation according to the invention is also illustrated in figure 2.

[0040] If the refrigeration consumer V' or its evaporator,

for example, is to be defrosted, the modified linear compressor x and the modified expansion valve a are moved into the working position in which flow through the modified linear compressor x and the modified expansion valve a is possible without a significant pressure loss in the refrigerant. According to the invention, the warm refrigerant now passes out of the refrigeration consumers V'' and/or V''', via the line 3', through the opened, modified linear compressor x to the evaporator of the refrigeration consumer V' and defrosts the latter. The refrigerant which has been cooled and possibly condensed as a result of the defrosting process is fed back to the (central) feed line 1 via the line 2', the opened modified expansion valve a and the line 1', and then passes back to the refrigeration consumers V'' and V''' via the lines 1''and 1'''.

[0041] If - as illustrated in figure 2 - bypass lines 4 and 5 are provided, the conventional expansion valve a' and the conventional compressor x' are taken out of operation and the refrigerant required to defrost the evaporator of the refrigeration consumer V' passes via the lines 3' and 5 to the evaporator of the refrigeration consumer V' that is to be defrosted. After defrosting has taken place, the refrigerant is then fed back to the (central) feed line 1 via the lines 2', 4 and 1'.

[0042] According to an advantageous configuration of the

refrigeration installation according to the invention, the refrigeration consumers V', V'' and/or V''' can - as illustrated in figure 1 - be connected to the feed line 1 and the discharge line 3 by means of couplings, preferably by means of quick-acting couplings K, in particular by means of standardized quick-acting couplings.

[0043] In addition or as an alternative to the procedure illustrated in figure 1, the refrigeration consumers V', V'', V''', … may also - as illustrated in figure 2 - be connected to one another in segments and directly, including the main lines 1 and 3. In this context, it should be ensured that under certain circumstances consumers or liquefiers at a different level - i.e. for example cold stores which are arranged on different floors of a hypermarket - are connected to one another, although in this case direct coupling or connection is not possible.

[0044] The flexibility of the refrigeration installation according to the invention can be increased further by means of these above-described advantageous configurations of the refrigeration installation according to the invention.

[0045] Both methods according to the invention for operating a refrigeration installation now make it possible for one or more refrigeration consumers that are to be defrosted simultaneously to be defrosted by the other refrigeration consumer(s) which are in the cooling phase. This is done without the need for additional pipe networks and/or

additional energy sources, as were required hitherto for compressed-gas defrosting.

[0046] As a refinement to the refrigeration installation according to the invention, it is proposed that

[0047] - the refrigeration consumer or at least one of the refrigeration consumers has a dedicated closed refrigerant (mixture) cycle,

[0048] - the refrigerant (mixture) cycle(s) is/are operatively connected via at least one liquefier to the feed line and the discharge line, and

[0049] - the refrigerant (mixture) cycle(s) in each case has/have modified expansion valves and/or modified linear expansion machines or conventional valves with associated bypass lines and modified linear compressors or conventional compressors with associated bypass lines,

[0050] - the evaporator of a refrigeration consumer in each case being arranged higher than the liquefier of the refrigeration consumer.

[0051] Figure 3 shows by way of example with reference to refrigeration consumer V' the above-mentioned configuration of the refrigeration installation according to the invention.

[0052] In this case, the refrigeration consumer V', V'' or V''' has a dedicated refrigerant (mixture) cycle 6, 7, 8 and 9, which is operatively connected via the liquefier E to the feed line 1 and the discharge line 3. The refrigerant (mixture) cycle 6, 7, 8 and 9 has either a modified expansion

valve a and a modified linear compressor x or a modified linear expansion machine, or else the conventional valve and/or the conventional expansion machine and the conventional compressor are assigned bypass lines, which are indicated by dashed lines in figure 3.

[0053] Those line portions and components which form part of the refrigeration consumer itself are surrounded in figure 3 by the dot-dashed line. This may optionally include the feed line 1 and discharge line 3.

[0054] In order now in defrosting operation to allow an automatic refrigerant (mixture) recirculation to be realized, it is necessary for the evaporator of the refrigeration consumer V' to be arranged at a higher level than the heat exchanger E.

[0055] This configuration allows the flexibility of the refrigeration installation according to the invention to be increased significantly compared to refrigeration installations of the generic type, since this configuration of the refrigeration installation according to the invention allows the (retrospective) inclusion of further refrigeration consumers in the refrigeration installation assembly.

[0056] As has already been mentioned, in the refrigeration installations of the prior art, it is always necessary to provide at least two separate refrigerant (mixture) cycles if both normal cooling and freezing points or consumers are to

be supplied with refrigeration. This problem is likewise eliminated by the refrigeration installation according to the invention, since now only one refrigerant (mixture) cycle needs to be provided.

[0057] The linear compressors that are to be provided are operated without oil. Therefore, the refrigeration installation according to the invention eliminates all the measures which have hitherto been required to separate off, recirculate, distribute and store the oil. Since transporting and distributing the oil within the pipe network is no longer of relevance, the individual lines or line sections can now be dimensioned exclusively on the basis of economic criteria.

[0058] The invention means that it is now no longer necessary to install what are known as combined refrigeration sets. Rather - at least in a relatively large area - it is possible for a large number of individual and if appropriate different refrigeration consumers to be linked into or removed from an existing system comprising liquid line, gas or pressure line and liquefier, if appropriate retrospectively. This is made possible in particular by virtue of the fact that it is possible to dispense with the above-described compressor sets of the combined refrigeration installations that have hitherto been required, since each refrigeration consumer now has its own compressor, which is adapted to the prevailing boundary conditions and specifics of the refrigeration consumer.